May 1995
NSRP 0445

SHIP PRODUCTION COMMITTEE
FACILITIES AND ENVIRONMENTAL EFFECTS
SURFACE PREPARATION AND COATINGS
DESIGN/PRODUCTION INTEGRATION
HUMAN RESOURCE INNOVATION
MARINE INDUSTRY STANDARDS
WELDING
INDUSTRIAL ENGINEERING
EDUCATION AND TRAINING

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Historical Overview of Efforts to Reduce VOC Emissions Through Coating Reformulations and Analysis of VOC vs HAP Content in Marine Coatings

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

in cooperation with
National Steel and Shipbuilding Company
San Diego, California

Report Documentation Page						Form Approved OMB No. 0704-0188

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1. REPORT DATE **MAY 1995**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **The National Shipbuilding Research Program, Historical Overview of Efforts to Reduce VOC Emissions Through Coating Reformulations and Analysis of VOC vs HAP Content in Marine Coatings**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Bldg 192 Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**61**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

DISCLAIMER

Historical Overview
of
Efforts to Reduce VOC Emissions
through
Coating Reformulations
and
Analysis of VOC vs. HAP Content in Marine Coatings
(Task #N1-89-2, Subtask 2)

Prepared and Submitted

by

NATIONAL STEEL AND SHIPBUILDING COMPANY

for

The National Shipbuilding Research Program

May 1995

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FOREWORD

The Environmental Studies and Testing Project, N1-89-2, was initiated to assist the shipyard community to comply with environmental regulations. The objective of the project was to provide a vehicle for the selection, definition, performance and analyses of certain physical testing and studies to support environmental considerations of shipyard work toward ultimate compliance with environmental regulations.

This study 'Historical Overview Of Efforts to Reduce VOC Emissions through Coating Reformulations' is being performed as sub-task 2 to the National Shipbuilding Research Program Project N1-89-2 within the purview of the SNAME SPC Panel SP-1 Ad Hoc Committee for Environmental Studies and Testing. The objective of the study is to demonstrate that the shipbuilding industry's and coating manufacturer's have voluntarily participated in efforts to reduce marine coating VOC contents.

In 1990 the United States Congress passed an amendment to the Clean Air Act. The amendment required Environmental Protection Agency to develop further control strategies for industrial emission sources. In 1993 EPA developed and released draft control technique guideline and national emission standard of hazardous air pollutant documents for the shipbuilding and repair industry. The scope of this study was expanded to review the relationship between the volatile organic compound content and the hazardous air pollutant content in marine coatings.

This project was written and prepared by Mr. Dan Buell who served as Project Manager and Mr. Willie M. Gaters who served as Project Engineer. Mr. Zack Jacobs also served as Project Engineer and provided technical assistance. This project has been peformed in conjunction with National Steel and Shipbuilding Company (NASSCO) who has ultimate responsibility for technical direction and publication of the final report.

EXECUTIVE SUMMARY

In 1990 the United States (U.S.) Congress adopted amendments to the Clean Air Act (1990 CAAA). The 1990 CAAA requires further control of volatile organic compound (VOC) and controls on hazardous air pollutant (HAP) emissions from air pollution sources. This report addresses a historical VOC overview of the U.S. shipbuilding and repair industry and coating manufacturers' role in reducing environmental impact of marine coating operations. These reductions came about because of improvements in marine coating technology.

In addition to requiring more control of VOC emissions, the 1990 CAAA requires U.S. Environmental Protection Agency (EPA) to develop a program to control hazardous air pollutant (HAP) emissions from shipyards. In mid 1994, EPA released a draftl NESHAP document for marine coating operations for comment. This document mirrors the requirements of the draft control technique guideline (CTG) document released in mid 1993 and later released as an alternative control technique (ACT) document for marine coating operations in mid 1994. The ACT controls VOC emissions from marine coating operations by limiting VOC content of coatings. The draft NESHAP also proposes to control HAP emissions from marine coating operations by limiting VOC content of coatings.

Historical California shipyard coating usage data was evaluated for this study. The historical data show that the four major-use coating categories used in marine coating operations alkyd, antioulant epoxy and inorganic zinc have been historically used at low volatile organic compound (VOC) content levels. This continual use of low VOC content coatings was achieved through advances in coating technology. The advances can be attributed to coating reformulations initiated by the shipbuilding industry and coating manufacturers and at times with input from regulatory agencies. There has been no previous documentation of efforts made by the shipbuilding industry and coating manufacturers to use environmentally friendly coatings.

To address the potential impact of the draft NESHAP, the scope of this project was expanded to identify the relationship between VOC and HAP content in solvent based marine coatings. The data shows that VOC and HAP contents levels in marine coatings are related. The general relationships among the four (4) identified major-use coating categories are; an increase or decrease in VOC content can result in either an increase or decrease HAP content, VOC content can be equal to or greater than the HAP constituents, as coating VOC content decreases the gap between VOC and HAP content may narrow until the VOC and HAP content equal.

1.0 INTRODUCTION

Title III of the Clean Air Act Amendment of 1990 (CAAA) establishes a regulatory program to control VOC and HAP emissions from industrial sources. VOC react with oxides of nitrogen (NOx) in a photochemical reaction to produce ozone or what's commonly known as smog. Smog affects the health and welfare of various individuals in the public. Thus far, EPA has identified and listed 189 pollutants as HAP. HAP have been determined to potentially pose increased cancer risk to individuals in the public.

In mid 1993 EPA released draft CTG and draft NESHAP documents identifying VOC and HAP emissions and potential controls for shipyard marine coating operations. The documents focused specifically on controls for marine coating operations within the shipyard. In mid 1994 EPA released an ACT document instead of the final CTG. The NESHAP document is now under a public comment period. From the ACT and draft NESHAP, control on both VOC and HAP emissions from shipyard marine coating operations will focus on limiting marine coating VOC content.

In an effort to address the CAAA'S new emphasis on air toxics, this report also attempts to identify the relationship between VOC and HAP contents in marine coatings. This marine coating historical VOC review and VOC content vs. HAP content evaluation will address the regulatory environment as it relates to California since it has one of the most stringent air pollution laws in the U.S.

Over the past 20 years, because of a cooperative effort between the shipbuilding industry and coating manufacturers, solvent based marine coating technology has advanced while maintaining a consistently low VOC content. This was accomplished through continual reformulations to improve coating peformance and reduce environmental impact. During the late 1980s air pollution laws were promulgated in California to control VOC emissions from marine coating operations. The laws were generally mirrored after existing and proven marine coating technology. The technology forcing regulations have been costly and cumbersome to meet in California. These stringent

regulations are not only onerous in nature from a shipyard production standpoint but also a marine coating reformulation technology standpoint. These limits have come to be known as the "1994 California limits."

Marine coating technological advances have not come without a significant price tag. It is extremely difficult to derive the exact price of the above efforts, but the cumulative industry cost is in the "millions *of* dollars." Marine coating manufacturers have confirmed that the cost to their companies to stay abreast of proposed marine coating regulations is between "a *quarter and halfa million dollars a year.* " *The* cost incurred by coating manufacturers are in turn passed onto shipyard costumers, namely U.S. Navy and commercial ship owners. This added cost of doing business is in turn likely contributing to decreased international competitiveness and increased operating costs for the shipbuilding industry. This report will illustrate the effort between the shipbuilding industry and coating manufacturers to improve coating performance to reduce environmental, health and safety and production impacts through continual coating reformulation.

2.0 VOC AND HAP AIR REGULATION

In the early 1970s the U.S. EPA developed National Ambient Air Quality Standards (NAAQS) for air pollutants. Through state implementation plans, states are required to meet these NAAQS. NOX and ozone are two air pollutants with established NAAQS'. Nitrogen Oxide or nitrogen dioxide (NOx) emissions are released from high temperature combustion processes. In the shipyard, the major source of NOX emissions are from fuel burning equipment such as boilers and internal combustion engines. Ozone (smog) is formed as a secondary pollutant through a photochemical reaction between NOX and VOC. In a shipyard, VOC emissions are generated from marine coating operations.

Historically, California has been in the forefront of developing environmental laws and regulations. This is most apparent in the area of air pollution control. In the early 1950s the first local agency was established in Los Angeles to protect citizens and properties from air pollution emissions. Soon after, a state agency was formed to control air pollution emissions from stationary sources. Eventually, in the early 1960s these agencies merged into the California Air Resources Board (CARB) to form a more comprehensive air pollution control program.

Because of California's significantly degraded air quality, the state adopted air quality standards more stringent than the federal NAAQS. In 1988 the state adopted the California Clean Air Act (CCAA). The CARB oversees control of all mobile sources emissions and has delegated authority to local air quality districts (Districts) to control stationary source emissions, which include emissions from shipyard operations.

2.1 FEDERAL REGULATIONS

In 1970 the U.S. Congress enacted the Clean Air Act (CAA). The objective of this regulation was to reduce the degradation of the nations air quality. In 1990 Congress amended the CAA.to strengthen regulatory requirements for controls of criteria pollutants such as VOC from stationary sources. The 1990 CAA amendment also identified a list of HAP (Appendix A: EPA HAP List). Shipyard marine coating operations area source of VOC and HAP emissions.

2.1.1 VOC REGULATIONS

The 1990 CAA amendment further required industrial sources to reduce VOC emissions. In mid 1993 EPA released a draft control technique guideline (CTG) document to control VOC emissions from marine coating operations. The draft CTG was later released in mid 1994 as an Alternative Control Technique (ACT) document without public comment. The major difference between a CTG and an ACT is that states do not have to adopt the ACT requirements. The U.S. EPA covered different approaches to reducing VOC emissions in the ACT. One approach discusses reducing VOC content of marine coatings. The 1994 California VOC or best available retrofit control technology (BARCT) is a standard also required in the federal, state and local California regulations. In most instances the majority of coatings that comply with these limits have not been used in actual ship production settings and are therefore unproven in the shipbuilding industry. The BARCT standards will contribute to placing U.S. shipyards at a competitive disadvantage with international shipbuilders.

2.1.2 HAP REGULATIONS

Title III of the 1990 CAA amendment also aims to reduce emission of 189 chemicals identified as hazardous pollutants (HAP) from industrial sources (Appendix A EPA HAP List). The 1990 CAA amendment requires U.S. EPA to develop national emission standards for each of the listed hazardous air pollutants. In mid 1994 U.S. EPA released a draft NESHAP document for marine coating operations. An approach the U.S. EPA is evaluating is to cortrol HAP through control of coating VOC limits.

2.2 STATE AND LOCAL REGULATIONS IN CALIFORNIA

In 1966 South Coast Air Quality Management District (SCAQMD) adopted Rule 66 to reduce hydrocarbon or VOC emissions from stationary sources. VOC emissions contribute to smog formation. Smog has a negative effect on the health and welfare of the general public. In the late 1960s the Bay Area Air Quality Management District (BAAQMD) adopted Rule 4 to reduce hydrocarbon emissions from stationary sources. In the early 1970s the San Diego County Air Pollution Control District (SDAPCD) followed suit and adopted their version of Rule 66. All the early VOC rules limited the photochemically reactive compound (PRC) content in marine coatings.

In the late 1980's CARB adopted the California Clean Air Act. The California CAA was amended in 1992. The objective of the Caliiornia CAA was to improve the states air quality. In the late 1980's CARB released a draft suggested control measure (SCM) for marine coating operations for comments. The SCM was later released as a reasonably available control technology and best available retrofit control technology (RACT/BARCT) document. RACT is based on 1ow-VOC coating standards that can be met with available coatings. BARCT is based on technology forcing standards that are not currently available. BARCT

if reformulated coatings have been developed prior to its implementation date.

The RACT standard is set at a VOC limit of 340 g/1 for general use category coatings and higher VOC limits for specialty use category coatings. The BARCT standard is set at a lower than RACT standards and is based on a future compliance schedule. The RACT/BARCT was developed as a guide for local APCDS in developing local rules and regulations. From 1988 to 1990 SCAQMD, BAAQMD and SDAPCD each adopted marine coating Rules 1106,43 and 67.18 respectively. These marine coating rules were designed to control VOC emissions from marine coating operations by placing limits on marine coating VOC contents. The adoption of the state RACT/BARCT and the passage of marine coating operation specific rules by California Air Districts added additional regulatory factors to the reformulation equation to obtain further reduction of marine coating VOC contents.

3.0 MARINE COATING REFORMULATION

In the late 1960s several California Air Districts (APCDS) adopted variations of Rule 66 to control emissions of PRC from industrial sources. In order to comply with Rule 66 coating manufacturers reduced the PRC content of marine coatigs through reformulation of marine coatings. Since the early 1970's the shipbuilding industry and marine coating manufacturers have strived to develop and reformulate marine coatings to improve coating performance. Industry concerns supporting the development and reformulation of marine coatings include; improving worker health and safety and reducing environmental impact. The approach to reformulation has been to seek a balance between these varying requirements.

Throughout the regulatory development in the late 1970s, the shipbuilding industry has continuously attempted to work with regulatory agencies in developing and adopting "realistic" rules and regulations in controlling VOC emissions from marine coating operations. In the mid 1980s solvent substitutions with chlorinated solvents resulted in reduced coating VOC content. The reduced coating VOC was later discovered to adversely affect worker health and safety. Reformulation activities have resulted in the development of coatings posing reduced risk to employees and lower VOC emissions. From the late 1980s to the early 1990s specific marine coating regulations to control VOC emissions were developed and adopted by the State of California and local APCDS.

The reformulation efforts were generally spearheaded by the National Shipbuilding and Research Program (NSRP); a federally funded research program. The undertaking are accomplished through its technical research groups Panel SP-1, Environmental Effects and Facilities and Panel SP-3, Surface Preparation and Coatings. This effort between government and private industry has resulted in the completion of an extensive amount of marine coating research and development (R&D) activities. These R&D activities have reduced chemical exposure risks for workers, reduced VOC emissions and increased coating life cycle. At the same time the reformulation of these marine

coatings also resulted in development of lower VOC content solvent based coatings, water based coatings and coatings with increased solids content.

3.1 PRODUCTION CONCERNS

In general, the shipbuilding industry has only experienced limited success in specific application of water based coatings. A water based coating category used in shipbuilding is the inorganic zinc primer. Inorganic zinc primer is commonly used in shipbuilding as a preconstruction primer. Preconstruction primer functions to provide corrosion protection during shipbuilding cycles which can last for up to nine months for a single block. In the recent years, a shortfall with the water based inorganic zinc preconstruction primers has been its reduced capacity to provide corrosion protection at thinner and thinner application thicknesses. Thinner application thicknesses are required to take advantage of faster welding rates because of advancement in weld technology. To take advantage of these faster weld rates, the shipbuilding industry and coating manufacturers have shifted their focus towards the reformulation and development of solvent based inorganic zinc preconstruction primers which can be applied at thinner levels and provide the required corrosion protection.

This shift in focus, however may be fruitless because, as of date coating manufacturer's have not been able to develop a proven solvent based inorganic zinc preconstruction primer which complies with the 1994 California limit. This obstacle will surely place the U.S. Ship Industry at a disadvantage with foreign shipyards since they are currently utilizing the new solvent-based inorganic zinc preconstruction primers in their production processes to take advantage of advances in welding technology.

3.2 COST OF VOC REGULATIONS AND LIFE CYCLE EFFECTS

Several coating manufacturers were contacted regarding the possibility of quantifying the costs associated with reformulating coating systems to comply with the applicable environmental regulations and performance requirements. The suggested additional cost burden on coating manufacturers to continually stay abreast and ahead of the impending regulations exceeds 1/2 million dollars a year. This additional cost increase shipyard operating cost. Added costs which are subsequently passed on to Navy or commercial shipowners.

The cost is only one aspect of reformulation, it must be emphasized that coating reformulation can increase the potential risk for end use performance failures. If failure of a coating system occurs, a ships hull may need to be re-coated. This re-coating would result in increased waste material, particulate emission during blasting operations and VOC emission during coating application as well as added costs. Under this Iife-cycle scenario, there is a no net benefit for the environment.

4.0 MARINE COATING DATA ANALYSES

The availability of marine coating usage data was assessed in conducting a historical VOC content trend analysis. A review of marine coating regulatory requirements was also conducted to identify a baseline environmental standard for marine coatings. Because a California shipyard had the most complete marine coating usage data and California has one of the most stringent air pollution laws for marine coatings; the shipyard's usage data was used for the analyses (Appendix B: California Shipyard VOC Trend Data). A listing of marine coatings to evaluate was then generated from the shipyard usage data for the VOC vs. HAP analyses (Appendix C: California Shipyard VOC vs. HAP Data). The marine coatings identified for the VOC vs. HAP analyses were further narrowed down to coatings with available material safety data sheets (MSDS) detailing product constituents and constituent proportion.

For the historical VOC trend analyses, the data was broken down into "actual" ship production time frames for U.S. Navy ships manufactured in the California shipyard between 1977 and 1991. For exarnpIe if a ship was constructed between 1978 and 1980, the average VOC content of a coating category was calculated for the same period. For the marine coating VOC vs. HAP content analyses, the data was broken down for calendar years between 1985 and 1993 when data was available for a coating category.

The data analyzed for both the historical VOC content and VOC vs. HAP content analyses focused on the four major-use coating categories as determined by the EPA's draft CTG and draft NESHAP for the shipbuilding and repair industry[1]. The categories were based on an industry wide survey conducted by the EPA which demonstrated that approximately 90'% of all coatings used in shipyard marine coating operations fell within four major coating categories. The four major coating

1. Coatings which did not fall into one of tbe four major coating categories were not evaluated because they include many different types of coatings and only contribute 10% to total emissions from marine coating operations.

categories evaluated and their approximate usage quantities are shown in table A below

Table A: Major-use Coating Categories in Shipyards.

Coating Category	% Usage
Alkyd	10.1
Antifoulant	11.3
Epoxy	58.8
Inorganic Zinc	9.5

4.1 VOC AND HAP CALCULATIONS

The VOC content of marine coatings were determined by either one (1) of two (2) methods. The first method was to use the VOC content provided by the manufacturer on the coating MSDS. The second method was to calculate coating VOC content using the Midwest Research Institute methods and assumptions in instances where the VOC content was not provided on the coating MSDS (Appendix D: MRI Assumptions March 22, 1993). The average VOC content of marine coatings were then calculated for each coating category for "actual" shipbuilding periods.

The HAP content of a marine coating was calculated after identifying and verifying coating constituents as HAP using the Merck Index, U.S. EPA's HAP list and/or MRI's 'Alphabetical Index of Synonyms of Hazardous Air Pollutants Designated in the 1990 Clean Air Act Amendments.' After a marine coating constituent was verified as a HAP, HAP content was calculated using the MRI methods and assumptions. The average VOC and HAP contents were then calculated for each coating category for calendar years between 1985 to 1993.

4.2 HISTORICAL VOC TREND RESULTS

With the exception of the antifoulant coating category the alkyd, epoxy and inorganic zinc coating categories all experienced overall decreases ranging from 2% to 40% in average VOC content from 1977 to 1991 (see Table B below).

Table B. Average VOC content of marine coatings used between 1977 to 1991.

Building Periods	1	2	3	4	5	6	7
	‘77-78’	‘77-79’	‘78-80’	‘80-83’	‘85-86’	‘85-87’	1991
Coating Categories	Average VOC content (lbs/gal)						
Alkyd	3.41	3.44	3.44	3.47	3.68	3.77	2.89
Antifoulant	2.75	2.75	2.75	2.75	3.6	3.6	3.12
Epoxy	2.46	2.66	2.37	2.43	2.43	3	2.41
Inorganic Zinc	4.16	4.16	4.16	4.14	4.7	4.7	2.47

In the alkyd coating category the average VOC content gradually increased from 3.41 to 3.77 lbs/gal or 10% between building period “l” and “6” (1977-1980). The average VOC content dropped from 3.77 to 2.89 lbs/gal or23% between building period “6” and “7” (1985-1991). The overall decrease in alkyd VOC content between building period “l” and “7” (1977-1991) was 3.41 to 2.89 lbs/gal or 15°/0.

In the antifoulant coating category the average VOC content remained constant at 2.75 lbs/gal between building period “l” and “4” (1977-1983). The average VOC content increased from 2.75 to 3.6 lbs/gal or 24% between building period “4” and “6” (1980-1987). The average VOC content decreased from 3.6 to 3.12 lbdgal or 13% between building period “6” and “7” (1985-1991). There was a general increase in antifoukmt VOC content horn 2.75 to 3.41 lbs/gal or 19% between building period “l” and “7” (1977-1991).

In the epoxy coating category the average VOC content increased from 2.46 to 3.0 lbs/gal or 1 18% between building period “1“ and “6” (1980-1987). The average VOC content decreased from 3.0 to 2.41 lbs/gal or 20% between building period “6” and “7” (1985-1991). There was a general decrease in epoxy VOC content from 2.46 to 2.41 lbs/gal or 2%0 between building period”1” and “7” (1977-1991).

In the inorganic zinc coating category the average VOC content increased from 4.16 to 4.7 lbs/gal or 11% between building period”1” and “6” (1977-1980). The average VOC content dropped from 4.7 to 2.47 lbs/gal or 47% between building period “6” and “7” (1985-1991). The general decrease in inorganic zinc VOC content was from 4.16 to 2.47 lbs/gal or 40% between building period “l” and “7” (1977-1991).

4.2.1 HISTORICAL VOC TREND DISCUSSION

Between 1977 and 1991 reformulation and coating chemistry development was occurring and new coatings were being applied and evaluated for their performance characteristics and application productivity. It was discovered that some of the low VOC coatings of the late 1970’s and early 1980’s resulted in worker health and safety exposure problems. To resolve the worker health and safety exposure problems, the coatings were reformulated. With the reformulation of the coatings and the elimination of harmful constituents such as chlorinated solvent, the average coating VOC content increased in the mid 1980’s. Although this “repositioning” resulted in an increase in coating VOC content it resulted in significantly reducing any possible adverse health effects associated with the lower VOC emitting constituents.

In September 1989, the first local California APCD rule limiting marine coating VOC content went into effect. The VOC standards that were adopted addressed both the California RACT and BARCT requirements. The adoption of existing RACT

standards demonstrate the industry's and coating manufacturer's continued effort in maintaining use of and development of low VOC content marine coatings respectively. Due to the new requirements of the marine coating specific rules subsequently adopted by other local California APCDS: in the late 1980's with the exception of antifoulants, the average VOC content for alkyd epoxy and inorganic zinc coatings decreased. Although there has been significant improvements in lowering the average VOC content of marine coatings, the technology forcing requirements are challenges that coating manufacturers must continue to strive to achieve.

The regulatory community must understand that development of new coating technology is time consuming and requires a considerable amount of resources. These agencies must also understand that with the harsh environments marine coatings are exposed to, new marine coating technology must first be proven to meet a ship owner's requirements which can take years to accomplish. Figure 1 *illustrates the* average VOC content trend for the four major marine coating categories from 1977to 1991.

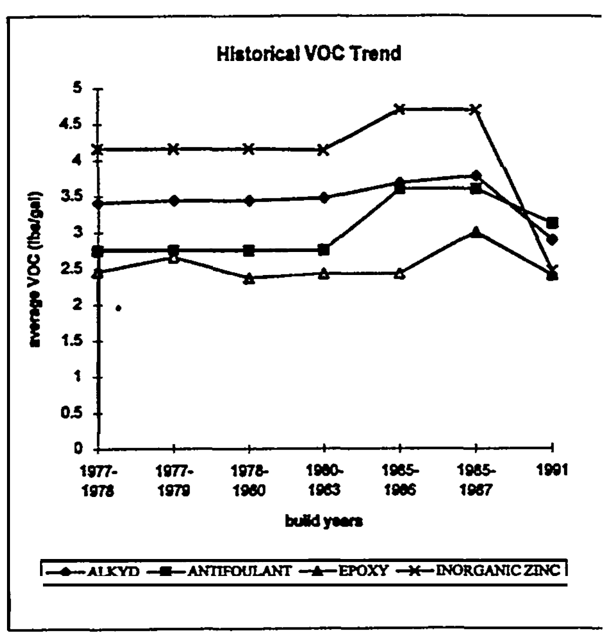


Figure 1: Average VOC content of marine coatings used from 1977 to 1991.

4.3 VOC vs. HAP RESULTS

In the alkyd coating category as the average VOC content generally decreased between 1985 and 1993, the average HAP content also decreased during the same period. Between this period, decreases in VOC content resulted in a narrowing of the difference between the VOC content and HAP content. The difference narrowed from 43% in the higher VOC content coatings to 15% in the lower VOC content coatings.

In the antifoulant coating category as the average VOC content generally decreased between 1985 and 1993, the average HAP content also decreased during the same period. Between this period, decreases in VOC content resulted in a narrowing of the difference between the VOC content and HAP content. The difference narrowed from 14% in the higher VOC content coatings to 0% in the lower VOC content coatings. In the case where the difference was 0%, the VOC content was equal to the HAP content.

In the epoxy coating category as the average VOC content generally increased from 1986 to 1993, the average HAP content also increased during the same period. Between this period, increases in VOC content resulted in a spreading-out of the difference between the VOC content and HAP content. The difference spread-out from 59% in the higher VOC content coatings to 89% in the lower VOC content coatings.

In the inorganic zinc coating category, as the average VOC content generally increased from 1989 to 1993 the average HAP content decreased during the same period. Between this period, increases in VOC content resulted in a spreading-out in the difference between VOC content and HAP content. The difference spread-out from 26% in the lower VOC content coatings to 46% in the higher VOC content coatings (see Table C below).

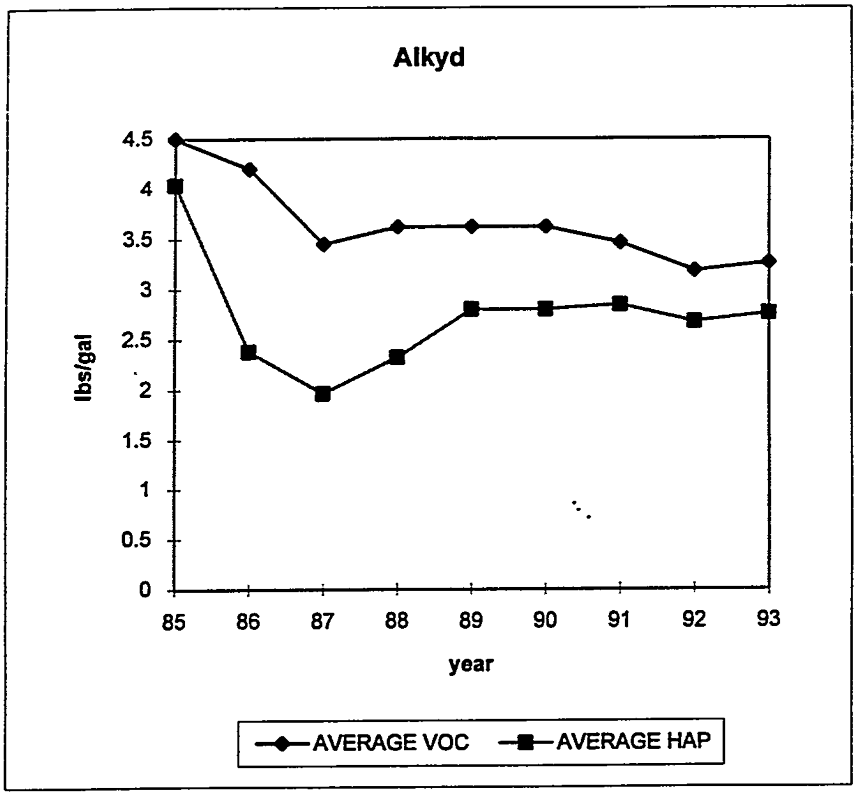
Table C. Average VOC and HAP content of marine coatings used between 1985 and 1993.

Year	Average VOC & HAP Content (lbs/gal)											
	alkyd			antifoulant			epoxy			inorganic zinc		
	VOC	HAP	% Difference	VOC	HAP	% Difference	VOC	HAP	% Difference	VOC	HAP	% Difference
85	4.5	4	10	4.48	3.85	14	NA	NA	NA	NA	NA	NA
86	4.2	2.4	43	3.66	2.51	31	1.83	0.21	89	NA	NA	NA
87	3.45	2	43	2.78	2.78	0	2.01	0.31	85	NA	NA	NA
88	3.62	2.3	36	3.7	2.86	23	1.96	0.36	82	NA	NA	NA
89	3.62	2.8	23	3.43	2.08	39	2.33	0.56	76	3.09	2.3	26
90	3.62	2.8	23	3.43	2.56	25	2.42	0.71	71	4.02	2.18	46
91	3.46	2.8	18	3.28	2.41	27	2.37	1.04	56	3.78	2.17	43
92	3.18	2.7	16	3.34	2.42	28	2.39	0.98	59	3.78	2.17	43
93	3.26	2.8	15	3.24	2.63	19	2.38	1	58	3.37	1.63	52

NA = no available data.

4.3.1 VOC vs. HAP DISCUSSION

From the coating data evaluated, there are three (3) general relationships that can be drawn between VOC content and HAP content in the four major marine coating categories. The first is there is no apparent trend between VOC and HAP content in any of the four major marine coating categories with either an increase or decrease in VOC content. In general an increase or decrease in VOC content can result in either an increase or decrease in HAP content. Second, the VOC content is always greater than or equal to the HAP content. Third, in the lower VOC content coatings the gap between VOC and HAP content narrow until the VOC and HAP content are equal. Figures 2 to 5 below illustrate these relationships:



[redacted]

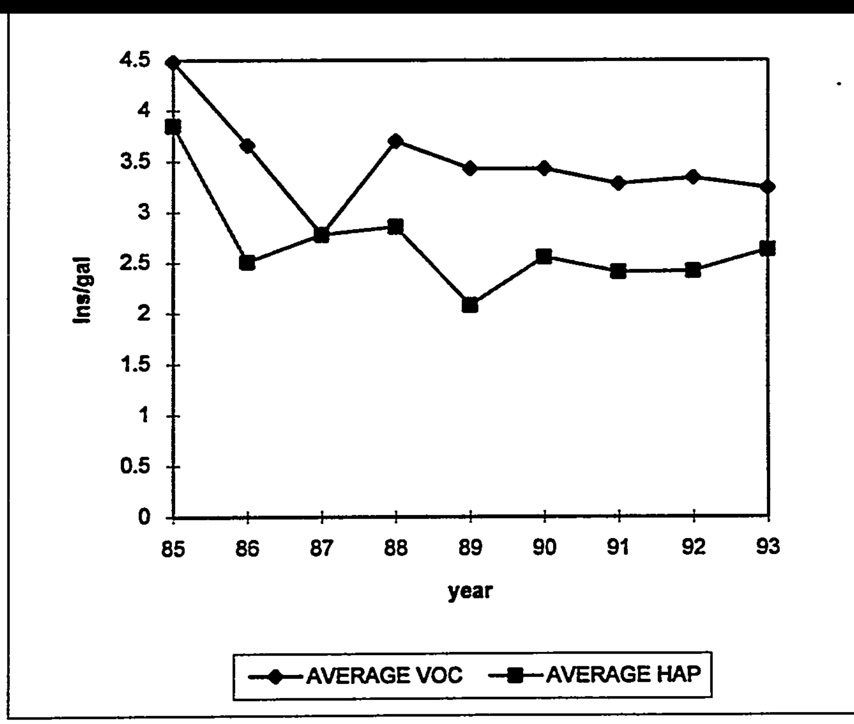


Figure 3: Average VOC and HAP content of antifoulant marine coatings used from 1985 to 1993.

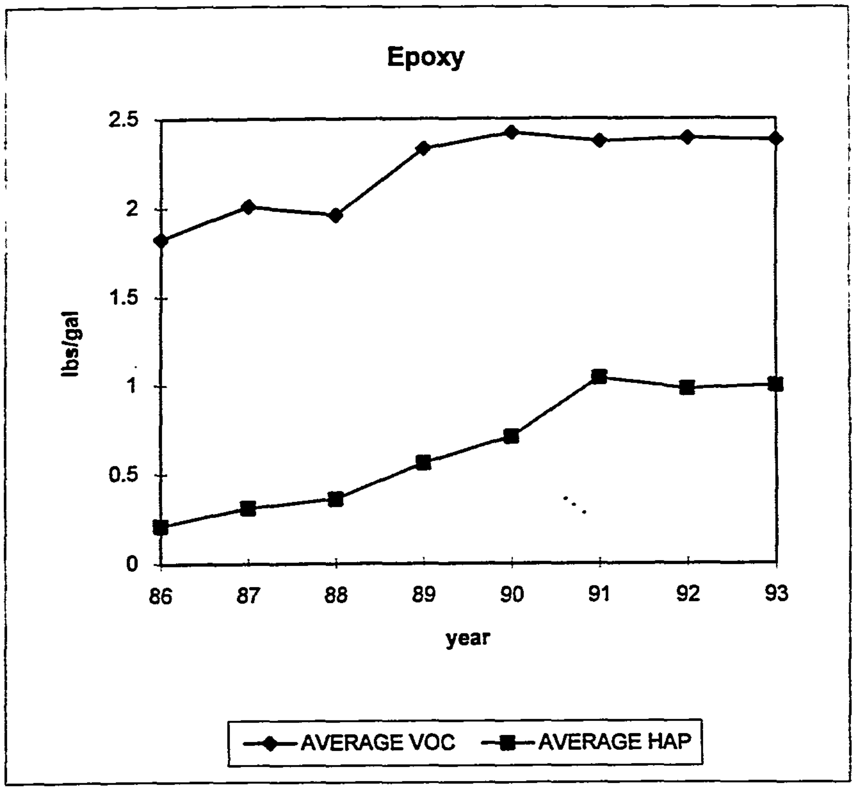


Figure 4: Average VOC and HAP content of epoxy marine coatings used from 1986 to 1993.

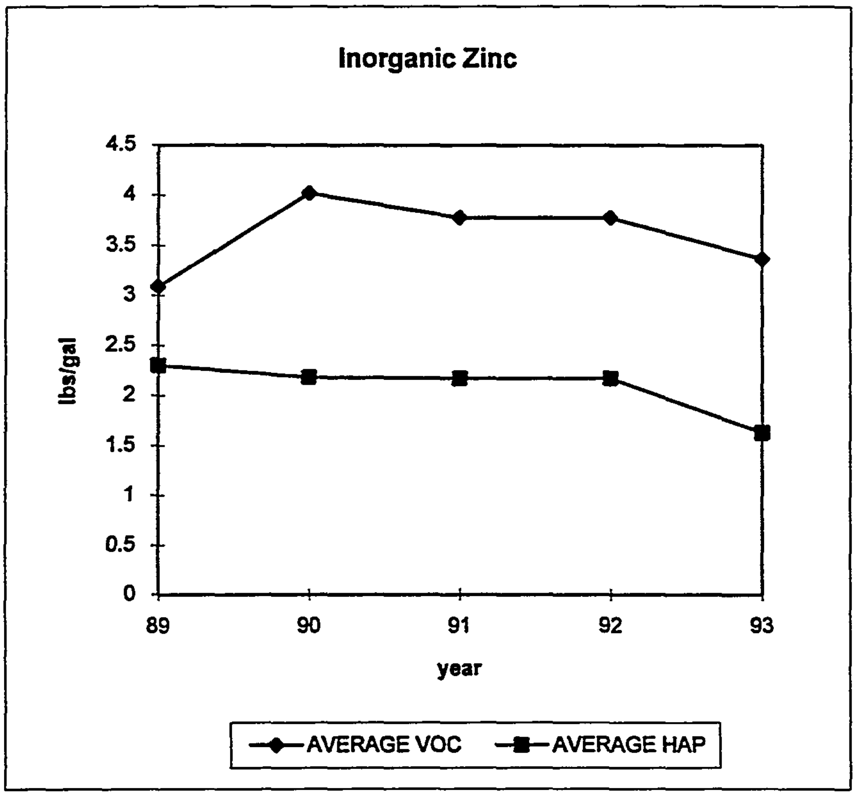


Figure 5: Average VOC and HAP content of inorganic zinc marine coatings used from 1989 to 1993.

5.0 **CONCLUSIONS**

The subject study indicates that the shipbuilding industry and supporting marine coating manufacturers have pro-actively, albeit at a significant cost developed improved coating technology that reduces worker health and safety impacts, improves performance needs and supports ever changing air quality regulations. Fortunately, the industry has influenced the regulatory community to develop generally “realistic” regulations to control VOC emissions that meet future needs and other equally important requirements.

As shown in the historical VOC trend analyses, the shipbuilding industry and marine coating manufacturers have made efforts to reduce the environmental, health and safety impacts of marine coatings through coating reformulations. In spite of these efforts, the shipbuilding industry and marine coating manufacturers have managed to improve the performance of marine coatings. Partnerships between the shipbuilding industry, coating manufacturers and governmental agencies, both research and regulatory bodies, have also contributed to reformulation efforts. Although there has been advancements, the partnerships must continue to work together to ensure firther improvements occur. Marine coating reformulation continues to be a viable approach to reducing VOC emissions, preventing worker exposure to harmful chemicals and improving coating performance. At this stage, further advances can only be made by finding the optimum balance between these equally important requirements. Furthermore, reductions in marine coating HAP emissions can also be made through finding the optimum balance between VOC and HAP content.

It must be emphasized, that the shipbuilding industry, must actively continue to control the direction of the environmental regulations, and as such continue to take a proactive approach to coating technology development and become influential and vocal in the regulatory rule development process to insure the passage of environmentally and industry “friendly” regulations.

APPENDICES

A. EPA HAP List.

B. California Shipyard VOC Trend Data.

C. California Shipyard VOC vs. HAP Data.

D. MRI Assumptions (March 22, 1993).

Appendix A

Listed Hazardous Air Pollutants

CAS number	Chemical name
75070	Acetaldehyde
60355	Acetamide
75058	Acetonitrile
98862	Acetophenone
53963	2-Acetylaminofluorene
107028	Acrolein
79061	Acrylamide
79107	Acrylic acid
107131	Acrylonitrile
107051	Allyl chloride
92671	4-Aminobiphenyl
62533	Aniline
90040	o-Anisidine
1332214	Asbestos
71432	Benzene (including benzene from gasoline)
92875	Benzidine
98077	Benzotrichloride
100447	Benzyl chloride
92524	Biphenyl
117817	Bis(2-ethylhexyl)phthalate(DEHP)
542881	Bis(chloromenethyl)ether
75252	Bromoform

CAS number	Chemical Name
106990	1,3-Butadiene
156627	Calcium Cyanamide
105602	Caprolactam
133062	Captan
63252	Carbaryl
75150	Carbon disulfide
56235	Carbon Tetrachloride
463581	Carbonyl sulfide
120809	Catechol
133904	Chloramben
57749	Chlordane
7782505	Chlorine
79118	Chloroacetic acid
532274	2-Chloroacetophenone
108907	Chlorobenzene
510156	Chlorobenzilate
67663	Chloroform
107302	Chloromethyl methyl ether
126998	Chloroprene
1319773	Cresols/Cresylic acid (isomers and mixture)
95287	o-Cresol
108394	m-Cresol
106445	p-Cresol

CAS number	Chemical name
98828	Cumene
94757	2,4-D,salts and esters
3547044	DDE
334883	Diazomethane
132649	Dibenzofurans
96128	1,2-Diromo-3-chloropropane
84742	Dibutylphthalate
106467	1,4-Dichlorobenzene(p)
91941	3,3-Dichlorobenzidene
111444	Dichloroethyl ether (Bis(2-chloroethyl)ether)
542756	1,3-Dichloropropene
62737	Dichlorvos
111422	Diethanolamine
121697	N,N-Diethyl aniline (N,N-Dimethylaniline)
64675	Diethyl sulfate
119904	3,3-Dimethoxybenzidine
60117	Dimethyl aminoazobenzene
119937	3,3’-Dimethyl benzidine
79447	Dimethyl carbamoyl chloride
68122	Dimethyl formamide
57147	1,1-Dimethyl hydrazine
131113	Dimethyl phthalate

CAS number	Chemical name
77781	Dimethyl sulfate
534521	4,6-Dinitro-o-cresol, and salts
51285	2,4-Dinitrophenol
121142	2,4-Dinitrotoluene
123911	1,4-Dioxane (l,4-Diethyleneoxide)
122667	1,2-Diphenylhydrazine
106898	Epichlorohydrin (l-Chloro-2,3-expoxypropane)
106887	l,2-Epoxybutane
140885	Ethyl acrylate
100414	Ethyl benzene
51796	Ethyl carbamate (Urethane)
75003	Ethyl chloride (Chloroethane)
106934	Ethylene dibromide (Dibromoethane)
107062	Ethylene dichloride (1,2-Dichloroethane)
107211	Ethylene glycol
151564	Ethylene imine (Aziridine)
75218	Ethylene oxide
96457	Ethylene thiourea
75343	Ethylidene dichloride (1,1 -Dichloroethane)
50000	Formaldehyde
76448	Heptachlor
118741	Hexachlorobenzene
87683	Hexachlorobutadiene

CAS number	Chemical name
77474	Hexachlorocyclopentadiene
67721	Hexachloroethane
822060	Hexamethylene-1 ,6-Diisocyanate
680319	Hexarnethylphosphoramide
110543	Hexane “C
302012	Hydrazine
7647010	Hydrochloric acid
7664393	Hydrogen fluoride (Hydrofluoric acid)
123319	Hydroquinone
78591	Isophorone
58899	Lindane (all isomers)
108316	Maleic anhydride
67561	Methanol
72435	Methoxychlor
74839	Methyl bromide (Bromomethane)
74873	Methyl chloride (Chloromethane)
71556	Methyl chloroform (1,1,1 -Trichloroethane)
78933	Methyl ethyl Ketone (2-Butanone)
60344	Methyl hydrazine
74884	Methyl iodide (Iodomethane)
108101	Methyl isobutyl ketone (Hexone)
624839	Methyl isocyanate
80626	Methyl methacrylate
1634044	Methyl tert butyl ether

CAS number	Chemical name
101144	4,4-Methylene bis(2-chloroaniline)
75092	Methylene chloride (Dichloromethane)
101688	Methylene diphenyl diisocyanate (MDI)
101779	4,4’-Methylenedianiline
91203	Naphthalene
98953	Nitrobenzene
92933	4-Nitrobiphenyl
100027	4-Nitrophenol
79469	2-Nitropropane
684935	N-Nitroso-N-methylurea
62759	N-Nitrosodhnethylamine
59892	N-Nitrosomorpholime
56382	Parathion
82688	Pentachloronitrobenzene (Quintobenzene)
87865	Pentachlorophenol
108952	Phenol
106503	p-Phenylenediamine
75445	Phosgene
7803512	Phosphine
7723140	Phosphorus
85449	Phthalicanhydride
1336363	Polychlorinatedbiphenyls (Aroclors)
1120714	1,3-Propanesultone
57578	beta-Propiolactone

CAS number	Chemical name
123386	Propionaldehyde
114261	Propoxur (Baygon)
78875	Propylene dichloride (1,2-Dichloropropane)
75569	Propylene oxide
75558	1,2-Propylenimine (2-Methyl aziridine)
91225	Quinoline
106514	Quinone
100425	Styrene
96093	Styrene oxide
1746016	2,3,7,8-Tetrachlorodibenzo-p-dioxin
79345	1,1,2,2-Tetrachloroethane
127184	Tetrachloroethylene (Perchloroethylene)
7550450	Titanium tetrachloride
108883	Toluene
95807	2,4-Toluene diamine
584849	2,4-Toluene diisocyanate
95534	O-Toluidine
8001352	Toxaphene (chlorinated camphene)
120821	1,2,4-Trichlorobenzene
79005	1,1,2-Trichloroethane
79016	Trichloroethylene

CAS number	Chemical name
95954	2,4,5-Trichlorophenol
88062	2,4,6-Trichlorophenol
121448	Triethylamine
1582098	Trifluralin
540841	2,2,4-Trimethylpentane
108054	Vinyl acetate
593602	Vinyl bromide
75014	Vinyl chloride
75354	Vinylidene chloride (1,1 -Dichloroethylene)
1330207	Xylenes (isomers and mixture)
95476	o-Xylenes
108383	m-Xylenes
106423	p-Xylenes

CAS number	Chemical name
0	Arsenic Compounds (inorganic including arsine)
0	Beryllium Compounds
0	Cadmium Compounds
0	Chromium-Compounds
0	Cobalt Compounds
0	Coke Oven Emissions
0	Cyanide Compounds[1]
0	Glycol ethers[2]
0	Lead Compounds
0	Manganese Compounds
0	Mercury Compounds
0	Fine mineral fibers[3]
0	Nickel Compounds
0	Polycylic Organic Matter[4]
0	Radionuclides (including radon)[5]
0	Selenium Compounds

Note: For all listings above that contain the word "compounds" and for glycol ethers, the following applies: Unless otherwise specified, these listings are defined as including any unique chemical substance that contains the named chemical (i.e., antimony, arsenic, etc.) as part of that chemical's infrastructure.

[1] X'CN where X = H' or any other group where a formal dissociation may occur. For example KCN or $Ca(CN)_2$

[2] Includes mono- and di- ethers of ethylene glycol, diethylene glycol, and triethylene glycol R- $(OCH2CH2)_n$ -OR' where

n = 1,2 or 3

R = alkyl or aryl groups

R' = R,H, or groups that, when removed, yield glycol ethers with the structure:

R- $(OCH2CH)_n$ -OH. Polymers are excluded from the glycol category.

[3] Includes mineral fiber emissions from facilities manufacturing or processing glass, rock or slag fibers (or other mineral derived fibers) of average diameter 1 micrometer or less.

[4] Includes organic compounds with more than one benzene ring, and which have a boiling point greater than or equal to 100C.

[5] A type of atom that spontaneously undergoes radioactive decay.

Appendix B

CALIFORNIA SHIPYARD COATING RECORDS
NAVAL VESSEL

1977-1978

COATING	COATING CATEGORY	VOC CONTENT (lbs/gal)
104 DULL BLACK	ALKYD	3.8
111 GREY	ALKYD	3.1
122/27 GREY	ALKYD	3.3
124 LIGHT BLUE	ALKYD	2.9
124 WHITE	ALKYD	2.9
125 GREEN	ALKYD	2.9
126 GREY	ALKYD	2.9
20 GREY DECK	ALKYD	3.5
20L GREY DECK	ALKYD	3.5
23 RED DECK	ALKYD	3.1
24 BLACK DECK	ALKYD	3.4
30 WHITE	ALKYD	3.1
920 TINTED	ALKYD	4
HEAT RESISTANT ALUMINUM	ALKYD	5.3
TT-E-490 GREY	ALKYD	3.3
TT-E-490 WHITE	ALKYD	3.5
121 ANTIFOULANT	ANTIFOULANT	2.7
129 A/F BLACK	ANTIFOULANT	2.8
150 GREEN	EPOXY	3.2
152 WHITE	EPOXY	3.3
156 RED	EPOXY	2.8
207 BLUE	EPOXY	3.7
207 GREY	EPOXY	3.7
207 YELLOW	EPOXY	3.7
COAL TAR EPOXY	EPOXY	2.4
TAA 421/423	EPOXY	0.6
TAA 426/423	EPOXY	0.6
TAA 428/423	EPOXY	0.6
191 R/B INORGANIC ZINC (>8#)	INORGANIC ZINC	1.7
2410/2411 INORGANIC ZINC (>8#)	INORGANIC ZINC	4.8
4437 H/F INORGANIC ZINC (>8#)	INORGANIC ZINC	5.2
4437 L/F INORGANIC ZINC (>8#)	INORGANIC ZINC	5.8
84ZCP INORGANIC ZINC (>8#)	INORGANIC ZINC	3.3

COATING CATEGORY	AVERAGE VOC CONTENT (lbs/gal)
ALKYD	3.41
ANTIFOULANT	2.75
EPOXY	2.46
INORGANIC ZINC	4.16

CALIFORNIA SHIPYARD COATING RECORDS
NAVAL VESSEL

1977-1979

COATING	COATING CATEGORY	VOC CONTENT (lbs/gal)
104 DULL BLACK	ALKYD	3.8
111 GREY	ALKYD	3.1
122/27 GREY	ALKYD	3.3
124 LIGHT BLUE	ALKYD	2.9
124 TINTED	ALKYD	2.9
124 WHITE	ALKYD	2.9
125 GREEN	ALKYD	2.9
126 GREY	ALKYD	2.9
20 GREY DECK	ALKYD	3.5
20L GREY DECK	ALKYD·	3.5
229 GREY	ALKYD	4.4
23 RED DECK	ALKYD	3.1
24 BLACK DECK	ALKYD	3.4
30 WHITE	ALKYD	3.1
920 TINTED	ALKYD	4
HEAT RESISTANT ALUMINUM	ALKYD	5.4
TT-E-490 GREY	ALKYD	3.3
TT-E-490 WHITE	ALKYD	3.5
121 ANTIFOULANT	ANTIFOULANT	2.7
129 ANTIFOULANT	ANTIFOULANT	2.8
150 GREEN	EPOXY	3.2
152 WHITE	EPOXY	3.3
156 RED	EPOXY	2.8
207 BLUE	EPOXY	3.7
207 GREY	EPOXY	3.7
207 YELLOW	EPOXY	3.7
4472 BLUE	EPOXY	3.7
5442 RED	EPOXY	3.7
COAL TAR EPOXY	EPOXY	2.4
TAA 421/423	EPOXY	0.6
TAA 426/423	EPOXY	0.6
TAA 428/423	EPOXY	0.6
191 R/B INORGANIC ZINC (>8#)	INORGANIC ZINC	1.7
2410/2411 INORGANIC ZINC (>8#)	INORGANIC ZINC	4.8
4437 H/F INORGANIC ZINC (>8#)	INORGANIC ZINC	5.2
4437 L/F INORGANIC ZINC (>8#)	INORGANIC ZINC	5.8
84ZCP INORGANIC ZINC (>8#)	INORGANIC ZINC	3.3

COATING CATEGORY	AVERAGE VOC CONTENT (lbs/gals)
ALKYD	3.44
ANTIFOULANT	2.75
EPOXY	2.66
INORGANIC ZINC	4.16

CALIFORNIA SHIPYARD COATING RECORDS
NAVAL VESSEL

COATING	1978-1980 COATING CATEGORY	VOC CONTENT (lbs/gal)
104 DULL BLACK	ALKYD	3.8
111 GREY	ALKYD	3.1
122/27 GREY	ALKYD	3.3
124 LIGHT BLUE	ALKYD	2.9
124 TINTED	ALKYD	2.9
124 WHITE	ALKYD	2.9
125 GREEN	ALKYD	2.9
126 GREY	ALKYD	2.9
20 GREY DECK	ALKYD	3.5
20L GREY DECK	ALKYD	3.5
229 GREY	ALKYD	4.4
23 RED DECK	ALKYD	3.1
24 BLACK DECK	ALKYD	3.4
30 WHITE	ALKYD	3.1
920 TINTED	ALKYD	4
HEAT RESISTANT ALUMINUM	ALKYD	5.4
TT-E-490 GREY	ALKYD	3.3
TT-E-490 WHITE	ALKYD	3.5
121 ANTIFOULANT	ANTIFOULANT	2.7
129 A/F BLACK	ANTIFOULANT	2.8
150 GREEN	EPOXY	3.2
152 WHITE	EPOXY	3.3
264 MOBILE GREY	EPOXY	3.7
264 MOBILE WHITE	EPOXY	3.7
4472 BLUE	EPOXY	3.7
5442 RED	EPOXY	3.7
COAL TAR EPOXY	EPOXY	2.4
TAA 421/423	EPOXY	0.6
TAA 424/423	EPOXY	0.6
TAA 426/423	EPOXY	0.6
TAA 428/423	EPOXY	0.6
191 R/B INORGANIC ZINC (>8#)	INORGANIC ZINC	1.7
2410/2411 INORGANIC ZINC (>8#)	INORGANIC ZINC	4.8
4437 H/F INORGANIC ZINC (>8#)	INORGANIC ZINC	5.2
4437 L/F INORGANIC ZINC (>8#)	INORGANIC ZINC	5.8
84ZCP INORGANIC ZINC (>8#)	INORGANIC ZINC	3.3

COATING CATEGORY	AVERAGE VOC CONTENT (lbs/gal)
ALKYD	3.44
ANTIFOULANT	2.75
EPOXY	2.37
INORGANIC ZINC	4.16

CALIFORNIA SHIPYARD COATING RECORDS
NAVAL VESSEL

COATING	1980-1983 COATING CATEGORY	VOC CONTENT (lbs/gal)
104 DULL BLACK	ALKYD	3.8
111 GREY	ALKYD	3.1
124 INSIGNIA BLUE	ALKYD	2.9
124 PASTEL BLUE	ALKYD	2.9
124 WHITE	ALKYD	2.9
124 WHITE TINTED	ALKYD	2.9
125 PASTEL GREEN	ALKYD	2.9
20 GREY DECK	ALKYD	3.5
20L GREY DECK	ALKYD	3.5
229 GREY	ALKYD	4.2
229 WHITE	ALKYD	3.8
23 RED DECK	ALKYD	3.1
24 BLACK DECK	ALKYD	3.4
30 WHITE	ALKYD	3.1
39 GREEN STRIPING	ALKYD	3.5
40 RED STRIPING	ALKYD	3.5
42 YELLOW STRIPING	ALKYD	3.5
43 BLUE STRIPING	ALKYD	3.5
917	ALKYD	4
920	ALKYD	3.9
920 TINTED	ALKYD	3.9
HEAT RESISTANT ALUMINUM	ALKYD	5.3
HEAT RESISTANT BLACK	ALKYD	2.8
PURPLE STRIPING	ALKYD	3.5
TT-E-490 GREY	ALKYD	3.3
TT-E-490 WHITE	ALKYD	3.5
121 ANTIFOULANT	ANTIFOULANT	2.7
129 BLACK 140	ANTIFOULANT	2.8
150 GREEN	EPOXY	3.2
151	EPOXY	3.1
152 WHITE	EPOXY	3.3
4471	EPOXY	3.7
4471/4473 WHITE	EPOXY	3.7
4472 BLUE	EPOXY	3.7
5442 RED	EPOXY	3.7
JXA 206/JXA 210	EPOXY	2.4
TAA 421/423	EPOXY	0.6
TAA 424/423	EPOXY	0.6
TAA 426/423	EPOXY	0.6
TAA 428/423	EPOXY	0.6
191 R/B INORGANIC ZINC (>8#)	INORGANIC ZINC	1.7
2410/2411 INORGANIC ZINC (>8#)	INORGANIC ZINC	4.7
4437 H/F	INORGANIC ZINC	5.2
4437 L/F	INORGANIC ZINC	5.8
84ZCP INORGANIC ZINC (>8#)	INORGANIC ZINC	3.3

COATING CATEGORY	AVERAGE VOC CONTENT (lbs/gal)
ALKYD	3.47
ANTIFOULANT	2.75
EPOXY	2.43
INORGANIC ZINC	4.14

CALIFORNIA SHIPYARD COATING RECORDS
NAVAL VESSEL

COATING	1985-1986 COATING CATEGORY	VOC CONTENT (lbs/gal)
CL SERIES	ALKYD	4
CTB SERIES	ALKYD	3.9
HTA 724	ALKYD	4.1
KHA SERIES	ALKYD	2.7
MIL-P-15090	ALKYD	3.1
MIL-P-15146	ALKYD	3.7
MIL-P-18210	ALKYD	3.1
MIL-P-2934	ALKYD	3.2
TT-P-28	ALKYD	5.3
BFA SERIES	ANTIFOULANT	3.6
EFL SERIES	EPOXY	3.3
JXA 206/JXA 210	EPOXY	2.4
MIL-E-698	EPOXY	3.4
TAA SERIES	EPOXY	0.6
NQA021/NQA026	INORGANIC ZINC	4.7
QHA027/QHA028	INORGANIC ZINC	4.7

COATING CATEGORY	AVERAGE VOC CONTENT (lbs/gal)
ALKYD	3.68
ANTIFOULANT	3.6
EPOXY	2.43
INORGANIC ZINC	4.7

CALIFORNIA SHIPYARD COATING RECORDS
NAVAL VESSEL

1985-1987

COATING	COATING CATEGORY	VOC CONTENT (lbs/gal)
CL SERIES	ALKYD	4
CTB000	ALKYD	3.9
FORMULA 201	ALKYD	3.9
FORMULA 229	ALKYD	4.2
HTA 724	ALKYD	4.1
MIL-E-698	ALKYD	2.8
MIL-P-15090	ALKYD	3.1
MIL-P-15146	ALKYD	3.8
MIL-P-17970	ALKYD	2.9
TT-E-490 WHITE	ALKYD	3.5
TT-P-28	ALKYD	5.3
BKA SERIES	ANTIFOULANT	3.6
EF SERIES	EPOXY	3.3
KHA SERIES	EPOXY	2.7
CHUKOGO	INORGANIC ZINC	4.7
NQA021/NQA026	INORGANIC ZINC	4.7
QHA027/QHA028	INORGANIC ZINC	4.7

COATING CATEGORY	AVERAGE VOC CONTENT (lbs/gal)
ALKYD	3.77
ANTIFOULANT	3.6
EPOXY	3
INORGANIC ZINC	4.7

CALIFORNIA SHIPYARD COATING RECORDS
NAVAL VESSEL

COATING	1991 COATING CATEGOR	VOC CONTENT (lbs/gal)
3279 HEAT RESISTANT ALUMINUM	ALKYD	2.8
39 GREEN STRIPING	ALKYD	3.5
40 RED STRIPING	ALKYD	3.5
400 WHITE	ALKYD	0.5
401 WHITE	ALKYD	2.1
42 YELLOW STRIPING	ALKYD	3.5
43 BLUE STRIPING	ALKYD	3.5
5705	ALKYD	2.8
5708	ALKYD	2.8
CLB 000V	ALKYD	3.3
CLF 384 GREEN	ALKYD	3.3
CLL 274V	ALKYD	3.3
CPA 004V	ALKYD	2.8
HEAT RESISTANT BLACK	ALKYD	2.8
385 GREY	ANTIFOULANT	2.7
385 RED	ANTIFOULANT	2.7
698 GREY	ANTIFOULANT	3.4
698 RED	ANTIFOULANT	3.4
ABC #3 BLACK	ANTIFOULANT	3.4
150 GREEN	EPOXY	2.8
153 BLACK	EPOXY	2.8
EFB 000/FMA 725	EPOXY	3.3
EFB 134/FMA 725	EPOXY	3.3
EFL 274/FMA 725	EPOXY	3.3
EXA 410/412	EPOXY	2.7
EXA 411/412	EPOXY	2.7
FPD 052/FPA 327	EPOXY	1.6
FPJ 034/EPA 327	EPOXY	1.6
FPK 705/FPA 327	EPOXY	1.6
FPL 274/FPA 327	EPOXY	1.6
FPY 999/FPA 327	EPOXY	1.6
EP 4661H/EPA 076V	INORGANIC ZINC	2.6
EPA 075/EPA076V	INORGANIC ZINC	2.6
QHA 028/027	INORGANIC ZINC	4.7
TQ 437H/TQ 4375H	INORGANIC ZINC	0

COATING CATEGORY	AVERAGE VOC CONTENT (lbs/gal)
ALKYD	2.89
ANTIFOULANT	3.12
EPOXY	2.41
INORGANIC ZINC	2.48

Appendix C

NSRP PROJECT #N1-89-2, SUBTASK 2
HISTORICAL VOC ANALYSIS
HAZARDOUS AIR POLLUTANT (HAPS) CONTENTS OF MARINE COATINGS
NASSCO
PROJECT MANAGER: DAN BUELL
PROJECT ENGINEER: WILLIE M. GATERS
COATING MANUFACTURER DATA: INTERNATIONAL PAINT, INC., CO. (IPIC)

YEAR	COATING NAME	COATING CATEGORY	FORMULA #	COLOR	TOTAL HAPS CONTENT (# HAPS/gal)	TOTAL VOC CONTENT (# VOC/gal)
84.8	CLB000	Alkyd		Gloss White	0.33	4.00
85.11	CLB000	Alkyd		Gloss White	4.04	4.51
86.1	CLB000	Alkyd		Gloss White	3.77	4.46
86.3	5675	Alkyd		White	0.31	4.28
86.9	5326	Alkyd	DOD-E-1115	White	3.06	3.77
87	5675	Alkyd		White	0.31	4.28
87	5326	Alkyd	DOD-E-1115	White	3.06	3.77
87.4	5319	Alkyd	F-111	Lt . Grey	2.87	3.57
87.8	CLB000	Alkyd		Gloss White	3.77	4.46
87.9	5672	Alkyd	TTE-490E	Haze Grey	2.01	4.21
88	5326	Alkyd	DOD-E-1115	White	3.06	3.77
88	5319	Alkyd	F-111	Lt . Grey	2.87	3.57
88	CLB000	Alkyd		Gloss White	3.77	4.46
88.2	5347 F124	Alkyd		Soft White	2.94	3.53
88.7	5672	Alkyd	TTE-490E	Haze Grey	2.01	3.33
88.8	5675	Alkyd		White	0.31	3.47
88.9	5675	Alkyd		White	0.31	3.47
88.9	5672	Alkyd	TTE-490E	Haze Grey	3.33	3.33
89	5326	Alkyd	DOD-E-1115	White	3.06	3.77
89	5675	Alkyd		White	0.31	3.47
89	CLB000	Alkyd		Gloss White	3.77	4.46
89.2	5672	Alkyd	TTE-490E	Haze Grey	3.33	3.33
89.4	5319	Alkyd	F-111	Lt . Grey	2.87	3.57
89.9	CLB000V	Alkyd		H-Gloss White	3.26	3.26
89.9	5347 F124	Alkyd		Soft White	2.94	3.53
90	5675	Alkyd		White	0.31	3.47
90	CLB000	Alkyd		Gloss White	3.77	4.46
90	5672	Alkyd	TTE-490E	Haze Grey	3.33	3.33
90.4	5326	Alkyd	DOD-E-1115	White	3.06	3.77
90.8	5347 F124	Alkyd		Soft White	2.94	3.53
90.9	CLB000V	Alkyd		H-Gloss White	3.26	3.26
91	CLB000	Alkyd		Gloss White	3.77	4.46
91	CLB000V	Alkyd		H-Gloss White	3.26	3.26
91.4	5675	Alkyd		White	1.26	3.43
91.4	5347 F124	Alkyd		Soft White	2.94	3.53
91.4	5672	Alkyd	TTE-490E	Haze Grey	3.33	3.33
91.9	5705	Alkyd		Haze Grey	2.45	2.73
92	5347 F124	Alkyd		Soft White	2.94	3.53
92	CLB000V	Alkyd		H-Gloss White	3.26	3.26
92.1	CLB000	Alkyd		Gloss White	3.72	4.46
92.1	5708	Alkyd		Dark Grey	2.20	2.75
92.3	5707	Alkyd		White	2.22	2.78
92.3	5705	Alkyd		Haze Grey	2.20	2.75
92.3	5708	Alkyd		Dark Grey	2.20	2.75
93	CLB000V	Alkyd		H-Gloss White	3.26	3.26
93	5705	Alkyd		Haze Grey	2.20	2.75
93	5708	Alkyd		Dark Grey	2.20	2.75
93	5347 F124	Alkyd		Soft White	2.94	3.53
93	CLB000	Alkyd		Gloss White	3.72	4.46
93.7	5707	Alkyd		White	2.22	2.78
85.9	BKA007/8	Antifoulant	Interswift	Brown	3.85	4.48
86.5	BKA007/8	Antifoulant	Interswift	Brown	1.83	4.51
86.8	BKA007/8	Antifoulant	Interswift	Brown	1.82	1.96
86.9	BKA007/8	Antifoulant	Interswift	Brown	3.88	4.51
87.9	4054	Antifoulant	Mil-P-15931E	Black F129	2.77	2.77
87.9	4050	Antifoulant	Mil-P-15931E	Red F121	2.79	2.79
88	4054	Antifoulant	Mil-P-15931E	Black F129	2.77	2.77
88	4050	Antifoulant	Mil-P-15931E	Red F121	2.79	2.79
88.1	F151	Antifoulant	4050	RED	0.00	2.59
88.11	F129	Antifoulant	4054	Black	2.74	2.74
88.2	BFA256	Antifoulant		Pink	3.96	4.75
88.2	BFA254	Antifoulant		Plum	3.91	4.69
88.4	BFA256	Antifoulant		Pink	3.38	4.75
88.4	BFA254	Antifoulant		Plum	3.34	4.69

NSRP PROJECT #N1-89-2, SUBTASK 2
HISTORICAL VOC ANALYSIS
HAZARDOUS AIR POLLUTANT (HAPS) CONTENTS OF MARINE COATINGS
NASSCO
PROJECT MANAGER: DAN BUELL
PROJECT ENGINEER: WILLIE M. GATERS
COATING MANUFACTURER DATA: INTERNATIONAL PAINT, INC., CO. (IPIC)

YEAR	COATING NAME	COATING CATEGORY	FORMULA #	COLOR	TOTAL HAPS CONTENT (# HAPS/gal)	TOTAL VOC CONTENT (# VOC/gal)
88.9	BRA540	Antifoulant		Red	2.85	3.59
88.9	BRA542	Antifoulant		Black	2.85	3.59
89	F151	Antifoulant	4050	RED	0.00	2.59
89	F129	Antifoulant	4054	Black	2.74	2.74
89.2	BRA540	Antifoulant		Red	0.98	3.59
89.2	BRA542	Antifoulant		Black	0.98	3.59
89.2	BFA256	Antifoulant		Pink	3.24	4.75
89.2	BFA254	Antifoulant		Plum	3.17	4.65
89.4	4050	Antifoulant	Mil-P-15931E	Red F121	2.79	2.79
89.9	4054	Antifoulant	Mil-P-15931E	Black F129	2.77	2.77
90	4050	Antifoulant	Mil-P-15931E	Red F121	2.79	2.79
90	F151	Antifoulant	4050	RED	0.00	2.59
90	BFA254	Antifoulant		Plum	3.17	4.65
90	F129	Antifoulant	4054	Black	2.74	2.74
90	BFA256	Antifoulant		Pink	3.24	4.75
90.1	BRA542	Antifoulant		Black	2.85	3.59
90.1	BRA540	Antifoulant		Red	2.85	3.59
90.9	BRA540	Antifoulant		Red	2.75	3.77
90.9	4054	Antifoulant	Mil-P-15931E	Black F129	2.77	2.77
90.9	BRA642	Antifoulant		Black	2.29	2.75
90.9	BRA542	Antifoulant		Black	2.75	3.77
91	F129	Antifoulant	4054	Black	2.74	2.74
91	F151	Antifoulant	4050	RED	0.00	2.59
91	4054	Antifoulant	Mil-P-15931E	Black F129	2.77	2.77
91	BFA254	Antifoulant		Plum	3.17	4.65
91	4050	Antifoulant	Mil-P-15931E	Red F121	2.79	2.79
91	BFA256	Antifoulant		Pink	3.24	4.75
91.5	BRA640	Antifoulant		Red	2.29	2.75
91.6	BRA540	Antifoulant		Red	2.43	3.77
91.6	BRA542	Antifoulant		Black	2.43	3.77
91.7	BRA640	Antifoulant		Red	2.31	2.78
91.7	BRA642	Antifoulant		Black	2.31	2.78
92	BRA640	Antifoulant		Red	2.31	2.78
92	BFA254	Antifoulant		Plum	3.17	4.65
92	F129	Antifoulant	4054	Black	2.74	2.74
92	BRA642	Antifoulant		Black	2.31	2.78
92	BFA256	Antifoulant		Pink	3.24	4.75
92	4050	Antifoulant	Mil-P-15931E	Red F121	2.79	2.79
92	4054	Antifoulant	Mil-P-15931E	Black F129	2.77	2.77
92	F151	Antifoulant	4050	RED	0.00	2.59
92	BRA542	Antifoulant		Black	2.43	3.77
92	BRA540	Antifoulant		Red	2.43	3.77
93	4050	Antifoulant	Mil-P-15931E	Red F121	2.79	2.79
93	4054	Antifoulant	Mil-P-15931E	Black F129	2.77	2.77
93	BRA642	Antifoulant		Black	2.31	2.78
93	BRA640	Antifoulant		Red	2.31	2.78
93.7	F151	Antifoulant	4050	RED	2.01	2.61
93.7	BRA540	Antifoulant		Red	2.75	3.77
93.7	BFA254	Antifoulant		Plum	3.38	4.20
93.7	F129	Antifoulant	4054	Black	1.91	2.81
93.7	BRA542	Antifoulant		Black	2.75	3.77
93.7	BFA256	Antifoulant		Pink	3.38	4.20
86.7	FPD052	Epoxy		Off-White	0.00	1.70
86.9	FPJ034	Epoxy		Light Grey	0.42	1.95
87	5751 F156A	Epoxy	TPD-24441/7C	Red	0.00	3.53
87	FPD052	Epoxy		Off-White	0.00	1.70
87.1	FPJ034	Epoxy		Light Grey	0.00	1.56
87.4	FPL274	Epoxy	INTERGUARD	RED	0.00	1.73
87.4	FPK705	Epoxy		Haze Grey	0.00	1.70
87.9	FPJ034	Epoxy		Light Grey	0.00	1.72
87.9	5752 F156B	Epoxy	TPD-24441/7C	Red	2.16	2.16
88	5752 F156B	Epoxy	TPD-24441/7C	Red	2.16	2.16
88	FPK705	Epoxy		Haze Grey	0.00	1.70
88	5751 F156A	Epoxy	TPD-24441/7C	Red	0.00	3.53

NSRP PROJECT #N1-89-2, SUBTASK 2
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NASSCO
PROJECT MANAGER: DAN BUELL
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COATING MANUFACTURER DATA: INTERNATIONAL PAINT, INC., CO. (IPIC)

YEAR	COATING NAME	COATING CATEGORY	FORMULA #	COLOR	TOTAL HAPS CONTENT (# HAPS/gal)	TOTAL VOC CONTENT (# VOC/gal)
88.6	FPJ034	Epoxy		Light Grey	0.00	1.46
88.6	FPL274	Epoxy	INTERGUARD	RED	0.00	1.48
88.6	FPD052	Epoxy		Off-White	0.00	1.46
89.5	FPA327	Epoxy	REACTOR		1.26	1.26
89.7	FPD052	Epoxy		Off-White	0.00	1.60
89.8	FPJ034	Epoxy		Light Grey	0.00	1.60
89.8	5747B	Epoxy	F150	Green Primer	2.25	2.40
89.8	FPL274	Epoxy	INTERGUARD	RED	0.00	1.48
89.8	FPA327	Epoxy	REACTOR		1.26	1.26
89.9	5755	Epoxy	F153A	Black	0.00	3.47
89.9	5756	Epoxy	F154A	DK Grey	0.00	3.60
89.9	5753	Epoxy	TPD-24441/3C	White	0.00	3.30
89.9	FPA327	Epoxy	REACTOR		1.30	1.30
89.9	FPD052	Epoxy		Off-White	0.00	1.60
89.9	FPJ034	Epoxy		Light Grey	0.00	1.60
89.9	FPK705	Epoxy		Haze Grey	0.00	1.70
89.9	5754	Epoxy	Comp B		1.80	2.06
89.9	5747B	Epoxy	F150	Green Primer	1.25	2.40
89.9	5752 F156B	Epoxy	TPD-24441/7C	Red	2.16	2.16
89.9	5747A	Epoxy	F150	Green Primer	0.00	3.28
89.9	5749 F151	Epoxy	F151	Top Haze Grey	0.00	3.52
89.9	5749 F151	Epoxy	F151	Top Haze Grey	0.00	3.52
89.9	5751 F156A	Epoxy	TPD-24441/7C	Red	0.00	3.53
90	5754	Epoxy	Comp B		1.80	2.06
90	5756	Epoxy	F154A	DK Grey	0.00	3.60
90	FPK705	Epoxy		Haze Grey	0.00	1.70
90	5752 F156B	Epoxy	TPD-24441/7C	Red	2.16	2.16
90	5751 F156A	Epoxy	TPD-24441/7C	Red	0.00	3.53
90	5753	Epoxy	TPD-24441/3C	White	0.00	3.30
90.3	5749 F151	Epoxy	F151	Top Haze Grey	0.00	3.52
90.3	5747A	Epoxy	F150	Green Primer	0.00	3.28
90.3	5755	Epoxy	F153A	Black	0.00	3.47
90.3	5747B	Epoxy	F150	Green Primer	2.25	2.40
90.4	5747A	Epoxy	F150	Green Primer	0.00	3.28
90.6	FPJ034	Epoxy		Light Grey	0.00	1.60
90.8	FPJ034	Epoxy		Light Grey	1.09	1.60
90.9	FPA327	Epoxy	REACTOR		1.20	1.20
90.9	FPD052	Epoxy		Off-White	1.09	1.60
90.9	FPL274	Epoxy	INTERGUARD	RED	1.11	1.48
90.9	FPJ034	Epoxy		Light Grey	1.45	1.45
91	5755	Epoxy	F153A	Black	0.00	3.47
91	5747A	Epoxy	F150	Green Primer	0.00	3.28
91	5749 F151	Epoxy	F151	Top Haze Grey	0.00	3.52
91	5751 F156A	Epoxy	TPD-24441/7C	Red	0.00	3.53
91	5753	Epoxy	TPD-24441/3C	White	0.00	3.30
91	5752 F156B	Epoxy	TPD-24441/7C	Red	2.16	2.16
91.3	FPY999	Epoxy		Black	1.08	1.44
91.4	FPK705	Epoxy		Haze Grey	1.44	1.44
91.4	5754	Epoxy	Comp B		1.80	2.06
91.5	FPA327	Epoxy	REACTOR		1.20	1.20
91.5	5849 std 595	Epoxy		Grey	0.00	3.35
91.9	FPD052	Epoxy		Off-White	1.41	1.41
91.9	FPJ034	Epoxy		Light Grey	1.45	1.45
91.9	5747B	Epoxy	F150	Green Primer	2.75	2.80
91.9	FPL274	Epoxy	INTERGUARD	RED	1.47	1.47
91.9	5754	Epoxy	Comp B		1.80	2.06
92	FPK705	Epoxy		Haze Grey	1.44	1.44
92	FPJ034	Epoxy		Light Grey	1.45	1.45
92	5747A	Epoxy	F150	Green Primer	0.00	3.28
92	FPY999	Epoxy		Black	1.08	1.44
92	5753	Epoxy	TPD-24441/3C	White	0.00	3.30
92	FPA327	Epoxy	REACTOR		1.20	1.20
92	5754	Epoxy	Comp B		1.80	2.06
92	FPL274	Epoxy	INTERGUARD	RED	1.47	1.47

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PROJECT ENGINEER: WILLIE M. GATERS
COATING MANUFACTURER DATA: INTERNATIONAL PAINT, INC., CO. (IPIC)

YEAR	COATING NAME	COATING CATEGORY	FORMULA #	COLOR	TOTAL HAPS CONTENT (# HAPS/gal)	TOTAL VOC CONTENT (# VOC/gal)
92	FPD052	Epoxy		Off-White	1.41	1.41
92	5749 F151	Epoxy	F151	Top Haze Grey	0.00	3.52
92	5751 F156A	Epoxy	TPD-24441/7C	Red	0.00	3.53
92	5752 F156B	Epoxy	TPD-24441/7C	Red	2.16	2.16
92	5755	Epoxy	F153A	Black	0.00	3.47
92	5849 std 595	Epoxy		Grey	0.00	3.35
92	5747B	Epoxy	F150	Green Primer	2.75	2.80
93	FPK705	Epoxy		Haze Grey	1.44	1.44
93	FPL274	Epoxy	INTERGUARD	RED	1.47	1.47
93	FPJ034	Epoxy		Light Grey	1.45	1.45
93	5849 std 595	Epoxy		Grey	0.00	3.35
93	5751 F156A	Epoxy	TPD-24441/7C	Red	0.00	3.53
93	5753	Epoxy	TPD-24441/3C	White	0.00	3.30
93	5754	Epoxy	Comp B		1.80	2.06
93	5747A	Epoxy	F150	Green Primer	0.00	3.28
93	FPA327	Epoxy	REACTOR		1.20	1.20
93	5747B	Epoxy	F150	Green Primer	2.75	2.80
93	5752 F156B	Epoxy	TPD-24441/7C	Red	2.16	2.16
93	5749 F151	Epoxy	F151	Top Haze Grey	0.00	3.52
93	FPD052	Epoxy		Off-White	1.41	1.41
93.7	F153 5839	Epoxy	F153B	Black	0.00	3.47
93.7	FPY999	Epoxy		Black	1.40	1.40
87.1	QHA027	Inorganic Zinc	Powder		0.00	0.00
87.5	TQ4374H	Inorganic Zinc	Powder		0.00	0.00
87.5	TQ4374H	Inorganic Zinc	Base	Binder	0.00	0.00
88	TQ4374H	Inorganic Zinc	Base	Binder	0.00	0.00
88.6	QHA027	Inorganic Zinc	Powder		0.00	0.00
89	QHA027	Inorganic Zinc	Powder		0.00	0.00
89	TQ4374H	Inorganic Zinc	Base	Binder	0.00	0.00
89.2	QHA025	Inorganic Zinc	Base	Red Binder	4.31	4.31
89.8	EPA075V	Inorganic Zinc		Red Primer	2.59	2.69
89.8	EPA076V	Inorganic Zinc	Reactor		0.00	2.26
90	TQ4374H	Inorganic Zinc	Base	Binder	0.00	0.00
90	QHA025	Inorganic Zinc	Base	Red Binder	4.31	4.31
90.1	EPA076V	Inorganic Zinc	Reactor		0.00	2.26
90.1	QHA028	Inorganic Zinc	Base	Green Silicate	2.20	4.75
90.1	QHA027	Inorganic Zinc	Base		0.00	0.00
90.5	QHA028	Inorganic Zinc	Base	Green Silicate	2.20	4.75
90.9	QHA027	Inorganic Zinc	Base		0.00	0.00
91	QHA028	Inorganic Zinc	Base	Green Silicate	2.20	4.75
91	EPA076V	Inorganic Zinc	Reactor		0.00	2.26
91	TQ4374H	Inorganic Zinc	Base	Binder	0.00	0.00
91	QHA025	Inorganic Zinc	Base	Red Binder	4.31	4.31
91	QHA027	Inorganic Zinc	Base		0.00	0.00
92	QHA027	Inorganic Zinc	Base		0.00	0.00
92	QHA028	Inorganic Zinc	Base	Green Silicate	2.20	4.75
92	EPA076V	Inorganic Zinc	Reactor		0.00	2.26
92	TQ4374H	Inorganic Zinc	Base	Binder	0.00	0.00
92	QHA025	Inorganic Zinc	Base	Red Binder	4.31	4.31
93	QHA025	Inorganic Zinc	Base	Red Binder	4.31	4.31
93	QHA027	Inorganic Zinc	Base		0.00	0.00
93	EPA076V	Inorganic Zinc	Reactor		0.00	2.26
93.7	QHA028	Inorganic Zinc	Base	Green Silicate	2.20	4.75
93.7	TQ4374H	Inorganic Zinc	Base	Binder	0.00	0.00
93.7	TQ4374H	Inorganic Zinc	Powder		0.00	2.14

Appendix D

INTEROFFICE MEMORANDUM

MIDWEST RESEARCH INSTITUTE

March 22, 1993

TO: Project File

FROM: D. Reeves

SUBJECT: Criteria/Assumptions Used in Developing HAP Data Base

(1) All HAP data on marine paints was entered in units of pounds (lb) of HAP per gallon of coating, less water.

(2) All paints were categorized using the same criteria as used for the VOC data base. In effect, the same generic information for each paint was used as the basis for the HAP data base (i.e., yard, category, brand name, supplier, and annual usage [gal]).

(3) Decision was made to characterize each paint category based on the top 80 percent (by volume) of paints in each category. This allowed us to spend more time on collecting, verifying and analyzing HAP data on the "vital few" versus the "trivial many."

(4) Since no test method specifically for HAP's currently exists, information from Material Safety Data Sheets (MSDS's) was used to estimate HAP contents of each paint.

(5) Emissions from solids overspray were considered insignificant so only solvent HAP's were considered (and entered in the HAP data base).

(6) All solvents (including thinners) were assumed to be 100 percent emitted to the air upon application of the paint.

(7) In using MSDS information, the following assumptions were made:

- Any time a range was given, the midpoint was used (i.e., 10-15% = 12.5% - see example 1).
- Any time a maximum was given, the maximum value was used (i.e., <5% = 5% - see example 2).
- Mineral spirits were categorized as either aliphatic (20% HAP's) or aromatic (100% HAP's) - see example 3.

- Any proprietary hazardous ingredients were considered non-HAP (most are believed to be resins).

- A weight (%) basis was used whenever provided. If volume basis was used, a generic solvent density of 7.0 lb/gal was used to calculate HAP solvent contents. See example 4.

(8) Many of the shipyards provided incorrect/incomplete brand names or supplier/manufacturer names. This was/is particularly troublesome when a group (family) of paints share the same prefix or product number designation. The shipyards referred to a paint as FP series and there are 10 FP series paints, with varying HAP contents. Some paint manufacturers added a one or two character suffix to the old paint/product number to designate a new (CA) compliant version. If the shipyard failed to include all numbers/characters in the product number, we have no way of knowing which product was actually used. Several followup phone calls were made to shipyards and paint suppliers trying to clarify the data.

(9) As a crosscheck with the VOC data base, HAP contents of each paint were compared with VOC contents. Since most HAP solvents are VOC's, any paint with a HAP content greater than its corresponding VOC content was flagged. If the difference resulted from the assumptions involving ranges or maximum limits of HAP solvents, the HAP contents were changed (reduced) to match the verified VOC contents.

(10) Multiple components coatings (i.e., epoxies and some inorganic zinc coatings) were entered as "mixed" ("as applied") paints. Several phone calls and requests for product data sheets were made to calculate the combined HAP content of mixed coatings. There were numerous problems and much confusion involving mix ratios (by weight or volume) and how to actually calculate HAP contents of the combined components with only one component reported by the shipyard.

(11) All HAP (and VOC) data base information is on an "as supplied" basis. No thinning allowance was made for any of the paint data. A separate thinning solvent data base was developed to compliment the VOC/HAP data bases.

(12) Waterborne coatings were only a significant (>1%) portion of one paint category--inorganic zinc. The HAP content was reported and entered as 0 lb HAP/gal. Since the HAP units are lb HAP/gal ($-H_2O$) an adjustment was made to the reported usages of all waterborne inorganic zincs. Additional phone requests were made for product data sheets to determine volume % solids. If a 1,000 gal of a waterborne paint with 50 percent solids by volume was reported, the annual usage was

changed to 500 gal to reflect the less water usage see example 5.

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MATERIAL SAFETY DATA SHEE

May be used to comply with OSHA's Hazard Communication Standard 29CFR 1910.1200.
(THIS MSDS SUPERCEDES ANY PREVIOUS ISSUE)
PLEASE DIRECT TO THE APPROPRIATE DEPARTMENT IMMEDIATELY

Telephone No.: (713) 682-1711
Emergency Telephone No.: (713) 682-1711
Date of Preparation: 03/11/91
or Reference: /A3/39

INTERNATIONAL
MARINE DIVISION
MSDS BOOK

EXAMPLE 1

Section One: Product Identification

Prod. No.: NEA408
Prod. Name: INTERPLATE NEA408 EPOXY PRIMER RED
Prod. Class:

Section Two: Hazardous Ingredients

CAS	Name	% Wt. (Optional)	Occupational Exposure TLV	Occupational Exposure PEL	Vap. Pr (mm H) (@20°)
* 67-63-0	ISOPROPANOL / 2-PROPANOL	~~5-10~~	~~400.00 PPM~~	~~400.00 PPM~~	~~33.~~
* 1330-20-7	XYLENE / DIMETHYLBENZENE	10-15	100.00 PPM	100.00 PPM	10.
107-98-2	PROPYLENEGLYCOL METHYL ETHER / 2-PROPANOL, 1-METHOXY-	15-20	100.00 PPM	100.00 PPM	10.
* 108-10-1	METHYL ISOBUTYL KETONE / METHYL ISOBUTYL KETONE	10-15	50.00 PPM	50.00 PPM	15.
7789-77-7	DI-CALCIUM PHOSPHATE DIHYDRA / DI-CALCIUM PHOSPHATE DIHYDRA	5-10	N/A	N/A	N/

RANGE OF WT %'S

* CHEMICALS SUBJECT TO THE REPORTING REQUIREMENTS OF SECTION 313 OF THE EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT OF 1986, AND OF 40 CFR 372.

N/A Not Available

Section Three: Physical Data

Boiling Range 180-280 DEG. F — Vapor Density: Heavier than air [X] Lighter than air [ ]
Evaporation Rate: Faster than ether [ ] Slower than ether [X] — % Volatile Weight (Theoretical) 50 (52) — Lb/Gal. 10.4

Section Four: Fire and Explosion Hazard Data

Flammability Classification: OSHA: FLAMMABLE, CLASS I B — DOT: FLAMMABLE
Flash Pt.: 49 DEG. F (ASTM D3278-78) — LEL: 1.0 PERCENT BY VOLUME
Extinguishing Media: Foam [X] "Alcohol" Foam [ ] CO_2 [X] Dry Chemical [X] Waterfog [ ] Other [ ]

Unusual Fire and Explosion Hazards:
CONTAINS FLAMMABLE SOLVENT. DO NOT USE IN AREAS WHERE SPARK OR OPEN FLAME ARE PRESENT.

Special Fire Fighting Procedures:
SMOTHER FLAMES WITH ONE OF THE ABOVE EXTINGUISHING MEDIA. WATER MAY BE USED TO COOL UNOPENED CONTAINERS, BUT MUST NOT BE USED AS AN EXTINGUISHING MEDIA. TAKE CARE TO PREVENT SPREAD OF BURNING LIQUID WITH WATER.
CLOSED CONTAINERS MAY EXPLODE WHEN EXPOSED TO EXTREME HEAT.

EXAMPLE 2

MSDS DATE: 08/01/89
PRINT DATE: 08/01/89

MSDS NO.: 16-1218163-01
REPLACES: NEW

MATERIAL SAFETY DATA SHEET

SECTION I - PRODUCT IDENTIFICATION

PRODUCT NUMBER: 22983448
PRODUCT NAME: [redacted] BLUE WHITE BASE R-66

MANUFACTURER: [redacted] COATINGS COMPANY
4000 DUPONT CIRCLE, LOUISVILLE, KY 40207
EMERGENCY TELEPHONE: 800-424-9300 (CHEMTREC)
TELEPHONE: 502-897-9861

SECTION II - HAZARDOUS INGREDIENTS

INGREDIENT	PERCT. BY WT.	CAS NO.	ACGIH TLV (PPM)	OSHA PEL (PPM)	HAZARDOUS a	HAZARDOUS b	HAZARDOUS c	VAPOR (2) PRESSURE
TITANIUM DIOXIDE	30	13463-67-7	D	DD				NA
EPOXY RESIN	10	25068-38-6	NE	NE				NE
ACRYLIC RESIN	20			20				<4.6
PROPYLENE GLYCOL METHYL ETHER ACETATE	30	108-65-6	NE	NE				3.7
N-BUTYL ALCOHOL	<5	71-36-3	50 (C) SKIN	50		X	X	5.9
MINERAL SPIRITS	<5	NA	100	500				5
N-BUTYL ACETATE	<5	123-86-4	150	150			X	13

UPPER LIMIT %'s!

NOTE: This product does not contain ingredients considered carcinogens or potential carcinogens by ACGIH, Federal OSHA, NTP, IARC, or CAL/OSHA.

ABBREVIATIONS: NE-NOT ESTABLISHED, NA-NOT APPLICABLE, C-CEILING LIMIT, D-NUISANCE PARTICLE TLV 10 MG/M^3 TOTAL DUST, (C)-CARCINOGEN, (PC)-POTENTIAL CARCINOGEN, DD-INERT OR NUISANCE DUST PEL 15 MG/M^3 TOTAL DUST, (1) NOT ESTABLISHED. USE STODDARD SOLVENT AS A GUIDE, (2) mm Hg. (X) - HAZARDOUS ACCORDING TO: a-SARA 302/304, b-SARA 313, c-CERCLA 103a

SECTION III - PHYSICAL DATA

BOILING RANGE: 240 - 315 DEGREES F
PERCENT VOLATILE BY VOLUME: 56.63
POUNDS PER GALLON: 10.77
VOC: 526.67 (GRAMS/LITER)
VAPOR DENSITY: | X | HEAVIER | | LIGHTER THAN AIR
EVAPORATION RATE: | | FASTER | X | SLOWER THAN ETHER

VOC = 4.33 lb/gal

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

FLAMMABILITY CLASSIFICATION
OSHA CLASSIFICATION 29 CFR 1910.106 (a) PARTS 18-19.
FLAMMABLE LIQUID - CLASS IC

FLASH POINT (Setaflash): 80F
LEL: 1

EXTINGUISHING MEDIA
In case of fire use CO2 Dry Chemical, Foam, or other National Fire Protections Association (NFPA) approved method for treating Class B Fire.

UNUSUAL FIRE AND EXPLOSION HAZARDS
Keep containers tightly closed. Isolate from heat, electrical equipment, sparks and flame. Vapors may cause flash fire. Vapc may ignite explosively. Vapors may spread long distances and beyond closed doors. Due to pressure build-up, closed containe exposed to extreme heat may explode. Never use a welding or cutting torch on or near container (even empty) as product or i residue may ignite. During emergency conditions overexposure to decomposition products may cause a health hazard. Symptoms m not be immediately apparent. Obtain medical attention.

SPECIAL FIRE FIGHTING PROCEDURES
Summon professional firefighters. Use full protective equipment including self contained breathing apparatus. Water spray may ineffective. If water is used, fog nozzles preferable. If exposed to fire or extreme heat, water should be used to cool clos- containers and prevent pressure build up or possible auto-ignition.

SECTION V - HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE

ACUTE
- BREATHING: Irritation of the respiratory tract; headache, nausea, dizziness, weakness and fatigue. Extreme exposu can result in unconsciousness and even respiratory arrest.
- SKIN OR EYE CONTACT: Causes eye and skin irritation. May be harmful if absorbed through the skin.
- SWALLOWING: Can cause stomach and/or intestinal irritation, nausea, vomiting and diarrhea.

CHRONIC
Reports have associated repeated and prolonged occupational overexposure to solvents with permanent brain and nervou system damage. Prolonged or repeated breathing of spray mist and/or sanding dust over a period of years may cause dus disease of the lungs.

)ICAL CONDITIONS PRONE TO AGGRAVATION BY EXPOSURE
None, when used in accordance with safe handling and use information (See Section VIII).

PRIMARY ROUTE(S) OF ENTRY | X | SKIN | X | BREATHING | X | SWALLOWING

SECTION V Continued on Next Page

International. Interlux.

MATERIAL SAFETY DATA SHEET

PLEASE DIRECT TO THE APPROPRIATE DEPARTMENT IMMEDIATELY

Telephone No.: (713) 682-1711
Emergency Telephone No.: (713) 682-1711
Date of Preparation: 04/09/91
Our Reference: /AO/39

EXAMPLE 3

Prod. No.: CQL274
Prod. Name: INTERLAC FINISH RED
Prod. Class:

CAS No.	Chemical Name	% Wt. (Optional)	Occupational Exposure TLV	Occupational Exposure PEL	Vap. Pres. (mm Hg @20°C)
* 1330-20-7	XYLENE DIMETHYLBENZENE	25-30	100.00PPM	100.00PPM	10.
64742-95-6	AROMATIC PETROLEUM SOLVENT XXXXXXXXX	1-5	100.00PPM	100.00PPM	10.
872-50-4	N-METHYLPYRROLIDONE XXXXXXXXXX	1-5	100.00PPM	100.00PPM	0.
8032-32-4	MINERAL SPIRITS LIGROINE	10-15	100.00PPM	100.00PPM	7.
8030-30-6	VM&P NAPHTHA LIGROINE	1-5	300.00PPM	300.00PPM	15.
64742-88-7	MINERAL SPIRITS, EXEMPT LIGROINE	1-5	100.00PPM	100.00PPM	2.
* 7439-92-1	LEAD CPDS (AS LEAD) LEAD CPDS (AS LEAD)	0.242	0.05MG/M3	0.05MG/M3	N/A

CATEGORY 2 (100% HAP's)

CATEGORY 1 (20% HAP's)

* CHEMICALS SUBJECT TO THE REPORTING REQUIREMENTS OF SECTION 313 OF THE EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT OF 1986, AND OF 40 CFR 372.

N/A Not Available

Boiling Range: 249-410 DEG. F
Vapor Density: Heavier than air [X] Lighter than air [ ]
Evaporation Rate: Faster than ether [ ] Slower than ether [X]
% Volatile Weight (Theoretical): 54
Lb/Gal: 9.0

Flammability Classification: OSHA: FLAMMABLE, CLASS I B
DOT: FLAMMABLE
Flash Pt.: 50 DEG. F (ASTM D3278-78)
LEL: 1.0 PERCENT BY VOLUME

Extinguishing Media: Foam [X] "Alcohol" Foam [ ] CO_2 [X] Dry Chemical [X] Watering [ ] Other [ ]

Unusual Fire and Explosion Hazards:
CONTAINS FLAMMABLE SOLVENT. DO NOT USE IN AREAS WHERE SPARK OR OPEN FLAME ARE PRESENT.

Special Fire Fighting Procedures:
SMOTHER FLAMES WITH ONE OF THE ABOVE EXTINGUISHING MEDIA. WATER MAY BE USED TO COOL UNOPENED CONTAINERS, BUT MUST NOT BE USED AS AN EXTINGUISHING MEDIA. TAKE CARE TO PREVENT SPREAD OF BURNING LIQUID WITH WATER. CLOSED CONTAINERS MAY EXPLODE WHEN EXPOSED TO EXTREME HEAT. WATER MAY BE USED TO COOL UNOPENED CONTAINERS.

International.

EXAMPLE 4

FACSIMILE MESSAGE

No. of Pages Including Cover 3

6001 Antoine
P.O. Box 4806
Houston, TX 77210-4806
Phone (713) 682-1711
FAX (713) 684-1511
TLX 168859
TWX (910)881-1160

919-677-0065.

DESTINATION: MRI, CARY, N.C.

DATE: 22 DECEMBER 1992

TO: DAVE REEVES

TIME DISPATCHED:

FROM: JOHN KEUM

FAX NUMBER: 76407

RE: VOC'S.

CC:

DAVE,

1. PLEASE FIND ATTACHED COPY OF PRODUCT DATA SHEET FOR QHA027/QHA028 ZINC SILICATE PRIMER, AS REQUESTED.

2. WITH RESPECT TO YOUR QUESTION ABOUT CALCULATING VOC AND % VOLUME SOLIDS OF PRODUCTS FROM INFORMATION PROVIDED ON MSDS'S — IT DEPENDS WHETHER INFORMATION ON MSDS'S IS PROVIDED ON % VOLATILE WEIGHT, OR % VOLATILE VOLUME.

- IN CASE OF INFORMATION BEING ON % VOLATILE WEIGHT.

$$\text{VOC} \simeq \frac{\text{\% VOLATILE WEIGHT} \times \text{WEIGHT PER GALLON}}{100}$$

$$\text{\% VOLUME SOLIDS} \simeq 100 - \left(\frac{\text{\% VOLATILE WEIGHT} \times \text{WEIGHT PER GALLON}}{7.0}\right)$$

(ASSUMING THAT WEIGHT PER GALLON OF VOLATILE COMPONENT IS 7.0 LBS).

- IN CASE OF INFORMATION BEING ON % VOLATILE VOLUME

$$\text{\% VOLUME SOLIDS} \simeq 100 - \text{\% VOLATILE VOLUME}$$

$$\text{VOC} \simeq \left(\frac{\text{\% VOLATILE VOLUME} \times 7.0}{100}\right)$$

THESE CALCULATIONS GIVE APPROXIMATIONS OF VOC'S AND VOLUME SOLIDS. FOR TWO PACK MATERIALS YOU NEED TO CALCULATE VALUES FOR EACH COMPONENT SEPARATELY AND ALLOW FOR MIXING RATIO TO DETERMINE VALUES FOR MIXED PRODUCT.

REGARDS — HAPPY HOLIDAYS.

EXAMPLE 5

TO: MOHAMED SERAGELDIN

FROM: DAVE REEVES
DATE: 1993-02-25

RE: EXAMPLE CALCULATIONS FOR WATERBORNE COATINGS

THE ONLY SIGNIFICANT WATERBORNE USAGES ALL INVOLVED INORGANIC ZINC COATINGS. VOC = 0

PAINT ID #	REPORTED USAGE (GAL) W/ H_2O		VOLUME SOLIDS (PRODUCT) (FROM DATA SHEETS)		RECALCULATED USAGE (GAL) EXC. H_2O
3.001	1310	x	61%	=	799
6.01	3900	x	40%	=	1560
7.084	1605	x	40%	=	642
8.032	5721	x	57%	=	3261

THESE NEW USAGES WERE PUT INTO THE DATABASE AND ALL CALCULATIONS (FOR MODEL PLANTS, AVERAGE VOC CONTENT WERE REDONE. THE NET EFFECT WAS THE AVERAGE VOC CONTENT FOR ALL INORGANIC ZINC COATINGS WENT UP SINCE LESS VOLUME (GAL) WITH Ø VOC CONTENT WERE INCLUDED IN THE AVERAGE; FROM 4.38 #/GAL TO 4.54 #/GAL

SINCE THESE ARE TWO-COMPONENT PAINTS, WE COULDN'T USE THE MSDS INFORMATION, WE HAD TO REQUEST THE PRODUCT DATA SHEETS TO GET SOLIDS INFO AND THE RATIO FOR COMBINING COMPONENTS. ALSO, MOST OF THESE PRODUCTS ARE SUPPLIED IN PARTIALLY FILLED CONTAINERS !!!

REFERENCES

Merck &Co., Inc., " The Merck Index, Eleventh Edition", 1989.

Midwest Research Institute, “Alphabetical Index of Synonyms of Hazardous Air Pollutants Designated in the 1990 Clean Air Act Amendments”, September, 1992.

Additional copies of this report can be obtained from the
National Shipbuilding Research and Documentation Center:

http://www.nsnet.com/docctr/

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Transportation Research Institute
Marine Systems Division
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Ann Arbor, MI 48109-2150

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Fax: 734-936-1081
E-mail: Doc.Center@umich.edu